# National Weather Service
## Upper Air Data Continuity Study Test Plan for the Sippican B2 and Vaisala RS92 NGP Radiosondes



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**U.S. DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**
**National Weather Service/Office of Operational Systems**
**Field Systems Operations Center/Observing Systems Branch**

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## ACRONYMS AND ABBREVIATIONS

| TERMS | DEFINITION |
|---|---|
| MicroART | Microcomputer Automatic Radio-theodolite |
| BILS | Balloon Inflation Launch Shelter |
| CDU | Control Display Unit |
| DCA | Data Control Assembly |
| FSD | Frequency Setting Device |
| GMD | Ground Meteorological Device |
| GPS | Global Positioning System |
| hPa. | Hectopascal |
| IF | Intermediate Frequency |
| KHz | Kilohertz |
| LOS | Line-Of-Sight |
| Mb | Millibar |
| PSI | Pounds Per Square Inch |
| IB | Inflation Building |
| MHz | Megahertz |
| MSL | Mean Sea Level |
| NCDC | National Climatic Data Center |
| NEC | National Electrical Code |
| NFPA | National Fire Protection Association |
| NOTAM | Notice to Airman |
| PITS | Protocol Interface Tests Suite |
| RF | Radio Frequency |
| RRS | Radiosonde Replacement System |
| RSOIS | Radiosonde Surface Observing Instrument System |
| RTS | Radiosonde Test Stand |
| RWS | RRS Workstation |
| SDM | Station Duty Manual |
| SFSC | Sterling Field Support Center |
| SPS | Signal Processing System |
| SPSS | Statistical Package for the Social Sciences |
| TRS | Telemetry Receiving System |
| UHF | Ultra High Frequency |
| UPS | Uninterruptible Power Supply |
| UTC | Coordinated Universal Time |
| WMO | World Meteorological Organization |
| WSH | Weather Service Headquarters |

## 1.0 Introduction

The National Weather Service (NWS) has developed the Radiosonde Replacement System (RRS) to replace its antiquated Microcomputer Automatic Radiotheodolite (MicroART) system, which has been in operation since the late 1980s. Recent Types of radiosondes flown in the legacy NWS network include the Sippican B2®, and MARK II®. These radiosondes are being phased out of the NWS upper air network with the introduction of the new Global Positioning System (GPS) radiosondes.

One significant impact the new GPS radiosondes have on operations are changes to sensors for temperature, pressure, and relative humidity measurements. These current generation sensor suites have differing characteristics from legacy radiosondes. Two radiosonde vendors, Lockheed-Martin Sippican and Vaisala, have developed 1680-MHz GPS radiosondes of this new design.

Because of these known changes and the potential impact on the long-term climate upper air record, a NWS directive was implemented to ensure that credible data continuity studies be conducted. As a result, a data continuity study is needed for assessing impacts as a result of the change in instrumentation for climatic and meteorological conditions.

The Upper Air Data Continuity Study (DCS) will determine what component of the total change seen in the climatic data is a result of true climatic variation and what component is related to a change in sensor technology, algorithm changes, and new procedures. Climatic change can be deduced by eliminating other factors, such as seasonal and annual effects, as well as differences in measurement. This plan only focuses on the NWS approach to ascertaining the measurement differences.

### 1.1. Data Continuity Goals

Dr. Thomas C. Peterson and Imke Durre from the National Climatic Data Center (NCDC) wrote in their report for the 15 January 2003 Meeting of NOAA's Council on Long-term Climate Monitoring: "The goal of this report is to define a continuity strategy for the Radiosonde Replacement System (RRS) transition. But more than that, it is to develop some metrics to assess what the appropriate strategy should be. When working on this assessment, it became clear that consideration should be given to radiosonde continuity beyond the RRS transition, beyond it in both time and space. Specifically, this means looking to the more distant future of NWS radiosondes and also looking at the Caribbean Hurricane Upper Air Stations (CHUAS) that the NWS supports, particularly the Caribbean GCOS Upper Air Network (GUAN) stations."

"In order to adequately assess the bias caused by the RRS transition, it is recommended that approximately 200 dual sonde flights be performed at each station. There are also enough dual sonde flights for the 95% confidence limit on the impact of the RRS transition induced discontinuity on a CONUS averaged tropospheric time series to be less than 0.05°C. The 0.05°C threshold was selected because it is one third of the controversial difference between two global satellite-derived tropospheric temperature time series adjustments for the discontinuity associated with the NOAA-9 polar orbiting satellite."

"The dual sonde flights are recommended to take place at a minimum of 17 and preferably 19 carefully but subjectively selected NWS radiosonde climate stations: four stations in Alaska, nine in the CONUS, five in the tropical Pacific and one NWS station in the Caribbean. In addition, one NWS supported CHUAS GUAN station was recommended for dual sonde flights." They also wrote in their report: "The second of ten basic 'climate monitoring principles' endorsed by the National Research Council (NRC) and United Nations Framework Convention on Climate Change (UNFCC) is of particular relevance. It reads: Principle 2. Parallel Testing: Operate the old system simultaneously with the replacement system over a sufficiently long time period to observe the behavior of the two systems over the full range of variation of the climate variable observed. This testing should allow the derivation of a transfer function to convert between climatic data taken before and after the change. When the observing system is of sufficient scope and importance, the results of parallel testing should be documented in peer-reviewed literature."

"Radiosondes, which unarguably meet the 'sufficient scope' and 'importance' criteria mentioned in the preceding Principle, are tested for accuracy and reproducibility in environmental chambers or factory tests, but natural exposure cannot be fully simulated in artificial or limited flight conditions. Instrument biases can vary with altitude, sensor, atmospheric conditions, sun angle, time of day, and other changes. Atmospheric quantities are continuously variable in time and space. Therefore, to address these data continuity concerns and to adhere to the climate monitoring principles, repeated measurements of the same quantities in a range of field environments will likely be required in order to determine differences between dissimilar radiosonde suites."

All National Centers for Environmental Prediction (NCEP) centers use upper air data in the conduct of their mission. Upper air data is considered an important data set in the preparation of daily prognoses and analyses on the state of the atmosphere. First-guess fields are generated in their models for assessing the forecast periods. Examples of these are the various analysis charts, e.g., 1000, 925, 850, 500, 100, and 20 hPa charts, freezing level charts, and the aviation model. The Tropical Prediction Center (TPC) uses soundings in relation to the formulation and intensity of tropical weather. The Hydrometeorological Prediction Center (HPC) uses upper air data to ascertain the degree of heavy precipitation for determining drought situations based on the upper level high-pressure domes. The Climate Prediction Center (CPC) uses upper air data for monitoring climate variability and change. Other centers use the data in research and in the development of new products.

### 1.2 General DCS Operations

The general plan for DCS operations is as follows:

- Sites will have both MicroART and RRS installed and operated in tandem during DCS operations (refer to Section 4.5 DCS Operations);

- A flight train with both legacy and RRS radiosondes will be suspended in close proximity to each other under a balloon/flight train; and
- Dual launches will be conducted and the data processed, operationally, into "archive files" before being transferred to NCDC.

The upper air data is collected, processed, and disseminated as World Meteorological Organization (WMO) TEMP-35/PILOT-32 messages to the meteorological community and the public. Section 4.5 describes MicroART and RRS operations in detail.

### 1.3 DCS Observations

Sites have been selected and a schedule of dual observations has been planned. NWS will launch the dual radiosondes using a technique developed by the Sterling Field Support Center (SFSC). The technique allows for the capture of data from both radiosondes along with the GPS geometric heights. The technique is described in Attachment C, Guide to Dual Flight Operations: Preparing and Releasing a Dual Flight Bar.

### 1.4 Joint System Configuration

One of the difficulties with finding the bias in measurements is in understanding how upper air data is acquired. The radiosonde telemeters temperature, relative humidity, and pressure engineering measurements to the ground system. The engineering units process them into meteorological parameters and assign a time stamp, nominally 1-second in the Radiosonde Replacement System (RRS) and 6-second to the Micro-ART data. Heights and winds are then calculated based on this information along with positional data for the winds to be calculated. These data are then compiled into datasets for processing into their final form of coded messages for world-wide distribution and two NCDC archive files – a standard Federal Coordinator for Meteorological (OFCM) format and a "high-resolution" 6-second Micro-ART format. Note that RRS is delivering a 1-second BUFR format archive file to NCDC in addition to the OFCM formatted archive. The dual flight system configurations can be seen in Figures 1 and 2. Attachment B contains the format used for the legacy system MicroART levels data and the high resolution data format used with the Radiosonde Replacement System. The two issues resulting from this process related to the DCS are:

- The clocks between systems will drift causing an additional uncertainty to the measurement bias; and
- Geo-potential heights used by climatologists to compare data also have uncertainties due to errors in the temperature, relative humidity, and pressure measurements.

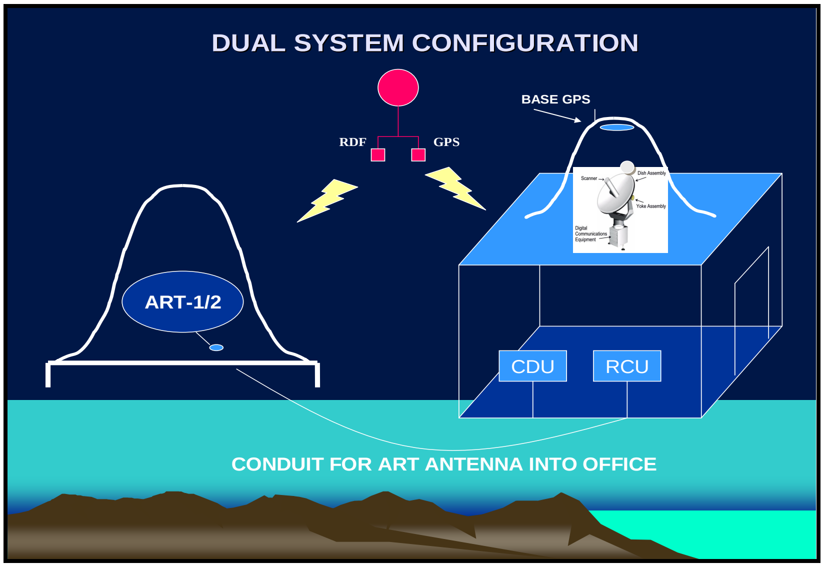


**Figure 1. Dual System Configuration**

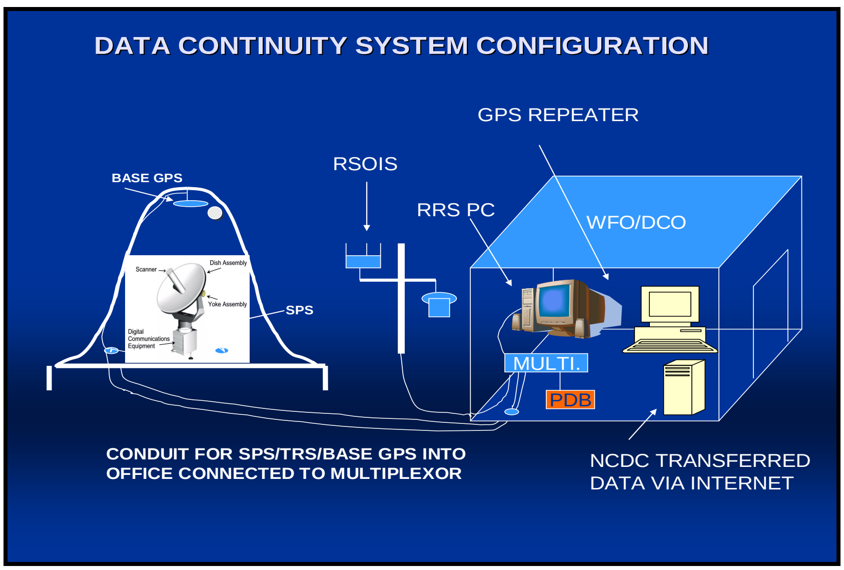


**Figure 2. Dual Continuity System Configuration**

## 2.0 DCS Plan

Below are the general plan components for the DCS as well as the requirements for its conduct.

## 2.1 NWS Site Selection

The NWS plans to meet these goals through the selection of NWS locations meeting the diversity of meteorological and Climatological conditions as suggested below. Figure 3 illustrates the candidates recommended for these locations. The 17 sites in the Petersen/Durre report constituted the NWS portion of the International Global Climate Observing Systems, Upper Air Sites.

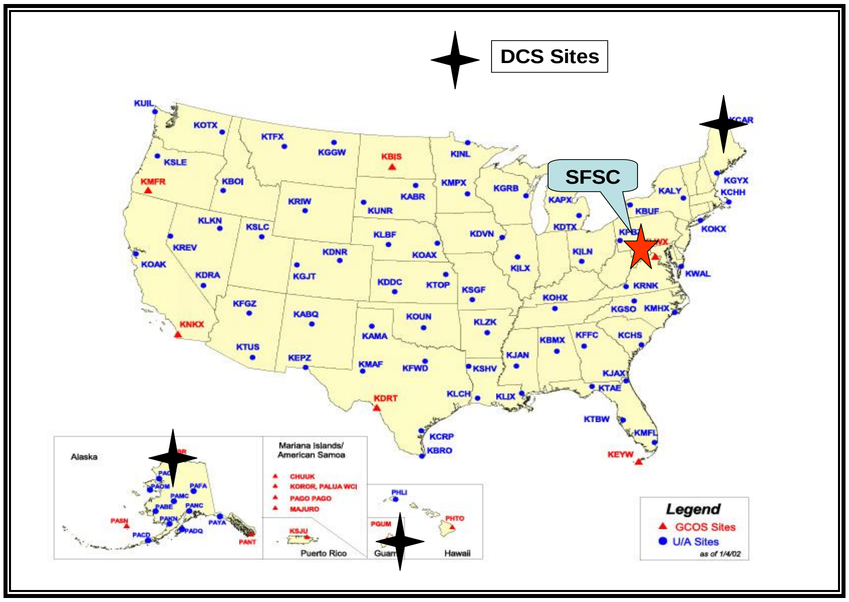


**Figure 3. Recommended Data Continuity Study Sites**

Budget considerations reduced the candidate DCS sites to three from the recommended 17. The three sites identified were Caribou, ME, Barrow, AK, and Tiyan, Guam. The SFSC test site at Sterling, VA has also been included as a fourth site, since it routinely performs this function as part of its test mission. The four stations selected are representative of the mid-latitudes, arctic and tropical climate regions of the U.S. network. The final DCS sites are identified with the large star.

### 2.1.1 SFSC Sterling, Virginia

The SFSC Sterling, Virginia site has a humid subtropical climate with warm summers. Its location in the middle latitudes has a general atmospheric flow from west to east which favors a humid subtropical climate with four well defined seasons. Summers are warm and at times humid. Winters are generally mild with the coldest period occurring in late January when temperatures average 21° F. The warmest period where temperatures average 88°F occurs in the latter part of July.

Precipitation is rather evenly distributed through the year. Annual precipitation has ranged from about 25 inches to more than 55 inches. Rainfalls of over 10 inches in a 24-hour period have been recorded during the passage of tropical storms. The seasonal snowfall is nearly 24 inches, but varies greatly from season to season. Snowfalls of 4 inches or more occur only twice each winter on average. Accumulations of over 20 inches from a single storm are extremely rare.

Prevailing winds are from the south except during the winter months when they are from the northwest. The windiest period is late winter and early spring. Winds are generally less during the night and early morning hours and peak during the afternoon. Winds may reach 50 to 60 miles per hour or higher during severe summer thunderstorms, hurricanes, and winter storms.

### 2.1.2 Caribou, ME

The Caribou site has a Humid Continental Climate with cool summers. While the location is 150 miles from the Atlantic coast, this factor does not alleviate the continental influences that result.

Winters are particularly long and windy, and seasonal snowfalls averaging over 100 inches are not unusual. Temperatures of zero or lower normally occur over 40 times per year.

Summers are cool and generally favored with abundant rainfall. Since Caribou, ME is located high up the St. Lawrence Valley, if often comes under the influence of the Summer Polar Front which results in practically no dry periods of more than three to four days.

Autumn weather is characterized by mostly sunny warm days and cool nights.

### 2.1.3 Barrow, AK

The Barrow upper air location is classified under the Polar Tundra climate. With the Arctic Ocean to the north, east, and west, and level tundra stretching 200 miles to the south, there are no natural wind barriers to assist in stalling the wind, permitting the lowering of temperatures by radiation, and no down slope drainage area to aid the flow of cold air to lower levels. Consequently, temperature inversions in the lower levels of the atmosphere are not extreme. Temperatures remain below the freezing point through most of the year, with the daily maxima reaching higher than 32°F on an average of only 109 days per year. Freezing temperatures have been observed every month of the year. February is generally the coldest month and March temperatures are slightly higher than those observed in the winter months. In April, temperatures begin a general upward trend, with May becoming the definite transitional period from the winter to summer season. July is the warmest month of the year and the frequency of minimum temperatures of 32 degrees or less are about one day out of two for July and August. During late July to early August, the Arctic Ocean is usually ice-free. Summer ends in September and by November, half of the mean temperatures are below zero as winter commences once again.

At 12:50 p.m. on November 18, the sun dips below the horizon and does not appear again until 11:51 a.m. on January 24. By 01:06 a.m. on May 10, the possible sunshine has increased to 24 hours per day and remains visible until August 2.

Sunshine appears to have a direct relationship to the occurrence of cloudiness, precipitation, and heavy fog. All three build up to a maximum with the hours of sunshine. Maximum cloudiness continues into the fall although the amount of sunshine, precipitation, and fog are on the decrease.

Wind speed variation during the year is small, with the fall months being windiest. Extreme winds in the upper 40s and the low 50s have been recorded in all months.

### 2.1.4 Tiyan, Guam

Guam's climate is classified as Tropical Wet and Dry. The location of the upper air site is on the western side of the Northern Plateau. Trade winds reach the station after rising sharply up the 500 foot cliffs on the eastern side of the island. The trade winds which blow from the east or northeast are strongest and most constant during the dry season, when wind speeds of 15 to 25 mph are very common. During the rainy season there is often a breakdown of the trades, and on some days the weather may be dominated by westerly-moving storm systems that bring heavy showers or steady, sometimes torrential rain. Occasionally, there are typhoons that bring tremendous rains as well as violent winds. The most frequent occurrence of typhoons is in the latter half of the year although they have passed sufficiently close to produce high winds and rain in every month.

The climate of Guam is almost uniformly warm and humid throughout the year. Afternoon temperatures are typically in the middle 80s and nighttime temperatures typically from the low 70s or high 60s. Relative humidity ranges from 65 to 70 percent in the afternoons to 85 to 100 percent at night.

There are two primary seasons and two secondary seasons in Guam. The primary seasons include the four-month dry season from January through April, and the four-month rainy season from mid-July to mid-November. The secondary seasons are May to Mid-July and mid-November through December. On average, about 15 percent of the annual rainfall occurs during the dry season and 55 percent during the rainy season.

## 2.2 System Descriptions

### 2.2.1 Micro-ART

Figure 4 delineates the types of systems in use today including the MicroART system (a variant of the Automatic Radiotheodolite for the Ground Meteorological Device or GMD).

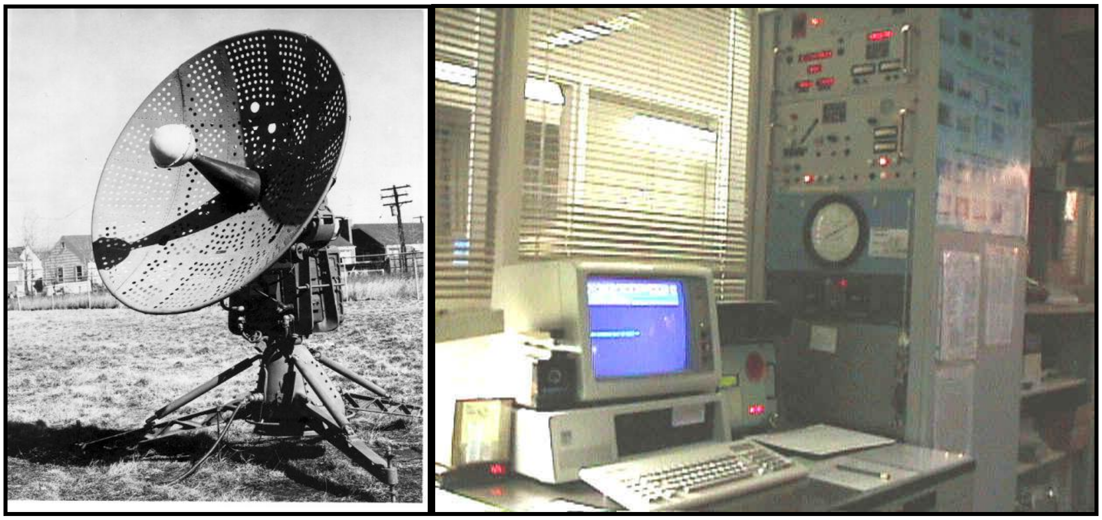

**Figure 4. MicroART System including Ground Meteorological Device**

Figure 5 lists the types of legacy radiosondes previous flown in the NWS network including the Sippican B2®, MARK II® variety, and the Vaisala RS 80®. The RS-80-57H was phased out of the network in the summer of 2010 and the Sippican (VIZ) B2 will be phased out of the NWS operated network by late summer 2013 and replaced with GPS-based radiosondes. Two radiosonde vendors, Lockheed Martin Sippican and Vaisala have developed radiosondes of this new design.

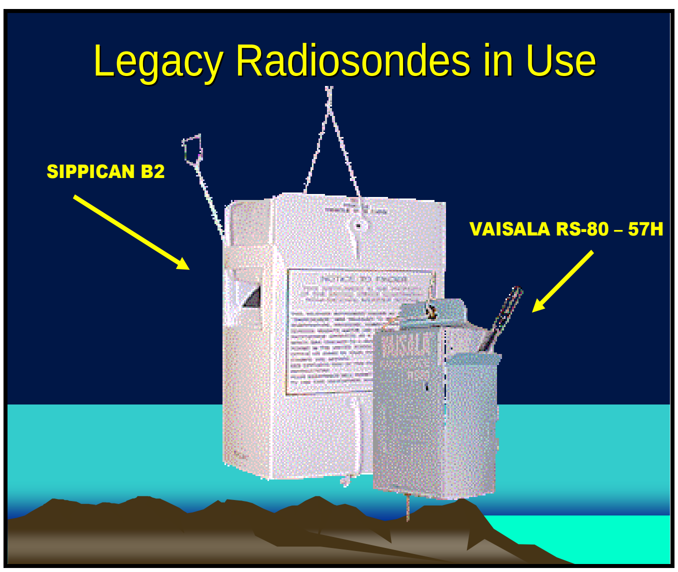


**Figure 5. Radiosondes flown with MicroART**

### 2.2.2 Radiosonde Replacement System

The RRS is comprised of a new GPS tracking antenna referred to as the telemetry receiving system (TRS), 1680 MHz GPS radiosondes and Signal Processing System (SPS), and a new NTbased workstation.  In addition to the deployment of the RRS, a new surface weather observing system called the Radiosonde Surface Observing Instrumentation System (RSOIS), and precision digital barometers were deployed at most of the102 locations from the Caribbean to Guam and from Alaska to Pago Pago, American Samoa in the Southern Hemisphere. Sites not using the RSOIS will use the Automated Surface Observing System (ASOS) and enter the observation manually into the workstation during prelaunch activities. GPS Repeaters are installed to improve GPS reception within the office environment during radiosonde baselining procedures.

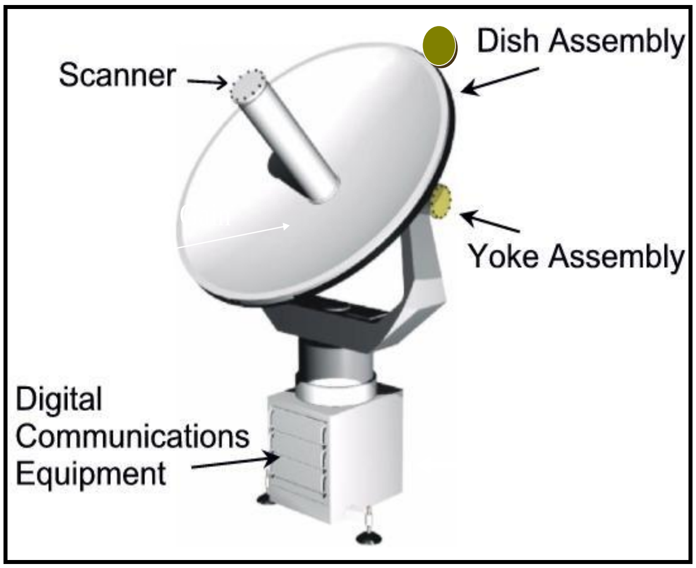


**Figure 6. RRS Antenna**

The RRS shown in Figure 6 has been deployed in a phased approach to most of the 91 locations scheduled to receive systems.  NWS will be conducting an Operational Test and Evaluation (OT&E) at selected sites in the spring 2012 for the Build 2 workstation software and another OT&E as part of the initial deployment of the climate-quality radiosonde.  The purpose of this latter OT&E will be to validate system/radiosonde usability, evaluate system/radiosonde performance in a field setting, and determine if any critical problems exist before build 2 software deployment commences.

## 2.3 Description of Radiosondes

### 2.3.1 Vaisala RS92-NGP Radiosonde

The Vaisala RS92 radiosonde uses a digital data transmission scheme modulated at 1680 MHz. The sensor suite consists of a silicon capacitive pressure sensor, a rode type capacitive temperature sensor and two alternately heated thin film capacitor sensors for RH measurement. A spiral GPS antenna is positioned on the top of the radiosonde and receives a GPS position every second which then translates into wind speed and direction. Figure 7 is the RS92-NGP radiosonde.  Sensor data are telemetered to the ground station at an approximate rate of once every second. At the ground station, the receiver demodulates the signal and sends the data to the

Vaisala signal processing system (SPS) in the pedestal of the TRS. The SPS converts the signal to meteorological units, and then passes the data via a fiber or RF link to the RWS in the office.

**Figure 7. Vaisala RS92-NGP Radiosonde**

The Vaisala frequency setting device must be used to set the frequency of the RS92 radiosonde frequency. This unit is simple to use and has four selectable frequencies. In addition to setting the frequency of the radiosonde, it also burns of contaminates which may have collected on the humidity sensors. Figure 8 is a picture of the device with the radiosonde in the cradle.


**Figure 8. Vaisala RS92-NGP Radiosonde on Frequency Setting Device**

### 2.3.2 LMS B2 1680-MHz Radiosonde

The LMS B2 radiosonde is an amplitude modulated 1680 MHz radiosonde which is depicted in Figure 9. The sensor suite consists of an aneroid pressure cell, a carbon element humidity sensor, and a ceramic rod resistive temperature sensor. Sensor data are telemetered to the ground station at an approximate rate of once every second. At the ground station, the receiver demodulates the signal and sends the data to the Automatic Radio Theodolite Interface Card (ARTIC) in the MicroART computer. The ARTIC card converts the signal to period values, and then passes the data to MicroART software version 2.92 for conversion to meteorological units. MicroART software filters, smooth's, and processes the data into a six-second data format which is used for coding messages and other files used by the NWS.


**Figure 9. Lockheed Martin Sippican B2 Radiosonde**

The Climate community's interest in the Lockheed Martin Sippican B2 legacy radiosonde originates from the fact that it is the last of a long line of radiosondes using the large rod resistive type temperature sensor dating back to the late 1950s. The large rod thermistor has been flown at the candidate DCS sites for an extended period and offers the best chance to get temperature change signatures. Attachment A contains a history of the legacy radiosondes using the large rod thermistor as well as other changes in Relative Humidity and pressure that also influenced radiosonde performance over the network in the past. Included in the appendix is individual station history information for the SFSC Sterling, Virginia site, Caribou Maine, Barrow, Alaska, and Tiyan, Guam.

## 3.0 DCS Requirements

The following sections describe the general requirements for the pre-requisites and conduction of the Data Continuity Study.

## 3.1 Pre-requisites for the DCS

The DCS is the culmination of a number of key steps as shown in Figure 10. Four major components to this process are as follows:

- Acquisition
- RWS Software
- Documentation
- Test cycles

The acquisition of the radiosondes to be used in the DCS will be climate-quality instruments. The radiosondes will be produced in a production facility which utilizes production quality control tests before delivering the instruments to the NWS for further testing. The updates required for the RWS Build 2 software for the new radiosonde and its associated development tests will be completed. All the documents which need to be generated in support of the new radiosonde including the RRS Workstation User Guide, software installation instructions, and the modification note to the RRS system for the new SPS must be completed. The System Test and Operational Test and Evaluation will be successfully completed before the NWS begins DCS operations. As indicated in Figure 10, several of these activities will be completed in parallel.

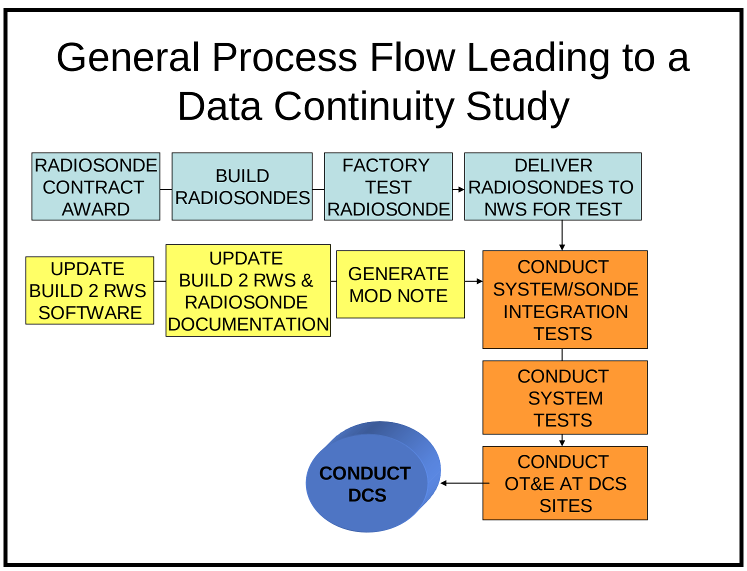


**Figure 10. Major Steps Leading to DCS**

## 3.2 Minimum Requirements

To ensure that there is sufficient data for the purposes of statistical analysis, the guidelines outlined in Table 1 will be used to determine the desired minimum number of valid flights reaching specific pressure levels:

| Flight Performance | Minimum Pressure | Required # of Flight |
|---|---|---|
| Minimum | 30 | 120 |

| | | |
|---|---|---|
| Target | 20 | 90 |
| Target | 10 | 75 |

**Table 1. Pressure level requirements by number of flights**

If the required number of flights is not met, the Weather Service Headquarters (WSH) may request additional flights to be conducted. An HM-32 type 1200 gram balloon will be used to ensure the payload reaches the highest possible altitude, although the target height is 10 hPa level, the minimum level for a successful flight is 30 hPa. Pressure levels to be evaluated in the report are, at a minimum: 1000, 925, 850, 700, 400 500, 250 300, 200, 150, 100, 70, 50, 30, 20, and 10 hPa. The DCS parameters for quantitative analysis are pressure/heights, temperature, and relative humidity. Winds will only be evaluated, qualitatively. In addition, since the SFSC will have time-synchronized releases the data will also be analyzed as a time-paired series. The SFSC will monitor and perform statistical analyses of each site's performance in terms of height requirements and data quality. Sterling will coordinate with NCDC to ensure all DCS data sets have arrived. Additional time may be required to meet the 120 required flights for the following reasons:

1. Office operations precludes a scheduled flight;
2. Weather conditions not conducive to either a successful flight or deemed unsafe for launch;
3. One or both radiosondes are deemed unsuccessful during flight – see Section 3.2.

Stations will select a day-of-the-week, e.g., Thursdays, to conduct both the 00Z UTC and 12 UTC dual flights and adhere to this schedule until the 120 number has been obtained. The day selected will be reported to the SFSC Project Manager (PM), Mr. Jim Fitzgibbon.

### 3.2.1 Successful Flight Requirements

For a DCS flight to be deemed successful, the following criteria must have been attained:

1. Baselining of both instruments have been conducted in accordance with NWS procedures, correctly;
2. Both radiosondes have obtained an altitude equivalent to at least the 30 hPa level with the goal being to obtaining 10 hPa;
3. Missing data does not exceed requirements found in NWS handbooks; and
4. Data from both radiosondes has been processed into bona-fide archive files and transmitted to NCDC with their acknowledgement of receipt.

Flights not meeting these requirements will be deemed unsuccessful. In these cases, dual flight will not count towards the minimum requirement; however, the data will be collected and held on site awaiting further guidance from the SFSC PM.

### 3.2.2 DCS Conclusion

When the above requirements have been fulfilled, the DCS will be concluded at each site independent from the other sites and guidance will be provided by the SFSC PM to terminate DCS operations. Actions to decommission and dispose of legacy equipment/expendables will be provided at that time.

### 3.3 Test Policy Requirements

Test policies and requirements will be followed during test operations. These policies have been established to maintain procedural consistency across sites and to ensure DCS data requirements are met. If at any time there is a question regarding the test and the question is not clearly addressed in the test plan, personnel are encouraged to contact the SFSC PM for guidance or clarification.

- During the DCS, the RRS will be operated as the official system of record and the Micro-ART legacy system will be in a secondary role. This means data edits and QC procedures will be applied to the RRS data. MicroART products will not be transmitted but will be archived using existing procedures. The SFSC will assist the site in making some minor necessary adjustments to these procedures in order to ensure proper archival of DCS data.
- Once the training team has departed the site, DCS soundings will be taken every seven days at the same synoptic time, 00 UTC and 12 UTC. A total of a 120 successful dual observations are required. Every effort should be made to maintain the seven day test cycle. Missed or unsuccessful DCS flights will be appended to the end of the test period. The test period is sixty weeks with an extension of 10 weeks for make-up flights.
- If it becomes apparent that two or more consecutive test flights will be missed, the SFSC should be notified. All missed flights will be recorded on the DCS web site. Plausible reasons for missing a test flight are as follows:

  - Office operations would be adversely impacted if site performs DCS flight as scheduled.
  - Conditions exist which may result in injury to personnel or property if the DCS flight is attempted.
  - One or both ground stations are working improperly.
  - Weather conditions are such that a successful release would not be likely.
  - At the request of the SFSC or NWSHQ.
  - No inflation gas available.

- For the DCS, a successful flight is one which reaches 30 hPa. If a flight is unsuccessful, no DCS second release will be attempted. **Station personnel will follow the local policy on second release requirements for the operational sounding.** If the MicroART radiosonde fails or is damaged during release and the RRS radiosonde is still functioning correctly, the flight will be continued for operational purposes. This flight will be logged as a failed DCS flight.
- Test personnel will determine if a flight has anomalies which may have an adverse impact on data quality. These flights will be flagged as suspect on the DCS web site. A test flight may be flagged as suspect for the following reasons:

    - Train assembly becomes entangled on radiosondes during release.
    - Radiosondes hit ground or other obstruction during release.
    - Interference of any kind is encountered on either or both systems.
    - Radiosonde malfunctions during flight.
    - Ground equipment problems occur during flight.
    - Any non-operational conditions exist that may result in an unfair comparison.

- Testing may be suspended if at any time the SFSC and WSH determine test objectives are being jeopardized for any reason. Additionally, if for any reason the site or regional headquarters wishes to suspend the test, requesting personnel will coordinate with the SFSC to have a conference call with all concerned parties to discuss the request. In either case the SFSC will mediate the appropriate action.

## 4.0 DCS Methodology

The following sections describe the general steps in the process at each field site in the study. Additional information can be found within the following resources:

- Guide to Dual Flight Operations: Preparing and Releasing a Dual Flight Bar
- Guide to Dual Flight Operations: Performance Checklist for Vaisala RS92-NGP and Sippican B2
- Guide to Dual Flight Operations: Techniques and Processes for Success

## 4.1 Test Preparation

The start date for the DCS is predicated on the site conducting the RRS deployment training requirements and approximately 30 days of using the system operationally. Operational use of RRS will be coincident with the *Operational Test & Evaluation (OT&E) Plan for Deployment of the Vaisala RS92* and the Radiosonde Replacement System (RRS) Workstation Subsystem (RWS) Build 2.2 software.

There are numerous activities which will need to be completed at least 60 days prior to the commencement of the DCS. These activities will be orchestrated by the SFSC and appropriate personnel from WSH. Site specific preparation will generally consist of station personnel familiarizing themselves with the DCS and associated processes. Station management will also need to schedule personnel for maximum participation in the SFSC onsite familiarization training. Stations can begin the DCS familiarization at their own discretion; however the SFSC recommends personnel begin this familiarization two weeks after the site begins operational use of the RRS. This will allow the site personnel an opportunity to build up their competency with the RRS before starting the DCS operations.

### 4.2 Test Metadata

For each of the DCS sites, SFSC personnel will conduct a comprehensive site survey for the MicroART, RRS and the surface observation equipment used for the surface observation associated with the upper air sounding. This information will constitute the site metadata for the DCS and will be part of the official test record. It will be provided to NCDC for archiving as part of test data record. A subset of these documents will also be available on the DCS web site. Attachment G is the SFSC DCS Site Survey Operating Procedure Manual for conducting site surveys and Attachment H is the template for development of the site Metadata file.

### 4.3 DCS Dual Flight Operations Familiarization.

The SFSC will be responsible for familiarizing site personnel in DCS dual flight operations. As a familiarization aid the SFSC will have a DCS dedicated web site. This site will have all documents associated with the DCS, but more importantly all familiarization material will be available through this site. Available material includes the following:

- Guide to Dual Flight Operations: Preparing and Releasing a Dual Flight Bar (Attachment C), which is a step-by-step guide for equipment warm-up, balloon inflation and train assembly, radiosonde preparation, and release site processes

- Guide to Dual Flight Operations: Performance Checklist for Vaisala RS92-NGP and Sippican B2 (Attachment D), which provides a sequence action checklist prior to and after the dual flight using both the Vaisala and Sippican B2 radiosondes

- Guide to Dual Flight Operations: Techniques and Processes for Success (Attachment E), which is a presentation that provides an overview of the dual flight process while justifying reasoning for common practices, also used during on-site DCS familiarization

- Guide to Dual Flight Operations: Vaisala RS92-NGP Preparation and Performance (Attachment F), a presentation which provides a more in-depth analysis of the radiosonde, how it should be handled and prepared, and its in-flight performance

- How to Perform a Successful Dual Flight video, which will assist observers in performing common flight procedures, such as preparing the flight train and releasing a dual flight bar

- Preparing Radiosondes for a Dual Flight video, which will assist the observer in preparing the Sippican B2 and Vaisala RS92-NGP radiosondes for a dual flight

- Data Continuity Study Input Form completion

Approximately one month (~30 days) after the site has successfully transitioned to RRS, they will independently begin the DCS and dual flight operations upon coordination with SFSC. On site familiarization for the DCS will take place during the first week when SFSC initially arrives to convert the site to RRS. This familiarization will consist of a 2 hour classroom session which will be followed by four to six DCS flights. These flights will be conducted at synoptic time and used as the operational sounding. On the first two flights, SFSC will run a data quality check as a means of verifying the integrity of the two ground stations. Additionally, these data sets will be retained by SFSC as the benchmark for monitoring system performance for the duration of the test. All familiarization flights which meet the DCS data requirements will be counted towards the total number of flights for the test.

| Activity | Start | duration |
|---|---|---|
| SFSC travel to test sites | Site specific to allow for travel | 2 days |
| Briefing and Site Q&A session | Day 1 (on site) | 1-2 hours |
| Systems check-out | Day 1 & 2 | 8 hours |
| Compile Metadata (surveys) | Day 1 & 2 | 12 hours |
| Classroom training | Day 3 | 2 hours |
| Start DCS training flights | Day 2 or 3 through day 5 (start first 00 UTC sounding after classroom session) | |
| Final DCS training Flight | Day 5 | |
| Finalize DCS Activities | | 2 days |

**Table 2. Schedule of SFSC Week One Onsite DCS Activities**

### 4.4 Radiosonde Test Stand

The SFSC will be responsible for the assembly and installation of the Radiosonde Test Stand (RTS). The RTS will be shipped as a kit ready for assembly. When the SFSC team arrives onsite for the training, they will work with site personnel to determine the best location for the RTS. Once the site is selected, SFSC personnel will coordinate or perform the assembly and installation of the RTS. However, if so desired, each site has the option to install the RTS in advance of the SFSC arrival. If they choose to install the RTS, they should first coordinate with the SFSC on the location. The RTS will be assembled and installed in accordance with the RTS Installation Instructions details in Attachment I. Figure 11 demonstrates the RTS used at the SFSC.

**Figure 11. SFSC Radiosonde Test Stand (RTS)**

For the field sites, the RTS will be nearly identical to what is pictured here. There is, however, another option which can be used to install the RTS. This utilizes a 61 cm (24 inch) mailbox spike which is pounded into the ground for a permanent installation.

## 4.5 DCS Operations

In order to meet test objectives and data requirements, test personnel should make every effort to follow the processes outlined in this document and its attachments. To capture the meteorological and climatic conditions which occur at each station, the test will cover a period of sixty weeks and consist of a minimum of 120 successful dual flights. Unsuccessful flights will be made up in the 10 weeks immediately following the original test period. Flights will be conducted every 7 days at 00 UTC and 12 UTC. Each site will select the day of the week for the DCS flight and this will not change. The flight train assembly, if assembled correctly will conform to the vertical height requirements in the ASTM D4430 Standard Practice for Determining Operational Comparability of Meteorological Measurements. This document specifies that for operational comparability of meteorological measurements should measure the same ambient atmosphere. To achieve this, the recommended measured cylindrical volume should be less than or equal to 10 meters in the horizontal and the vertical extent of the volume must be the lesser of one meter or one tenth of the height above the earth's surface of the base of the volume. Figure 12 shows the flight train and spreader bar assembly being properly prepared for flight.

**Figure 12. Preparation of dual flight train and spreader bar assembly**

Figure 13 illustrates the horizontal and vertical spacing relationship of the radiosondes as they are released and ascend through the atmosphere. Thus, care when attaching the radiosondes to the spreader bar should be taken to suspend the radiosondes at the same height with respect to each other.

**Figure 13. Dual flight bar release at SFSC**

## 4.6 NCDC Archive and Data Analysis

The following steps provide an outline of NCDC's responsibilities during and after the study:

**Data Transmission**
Dual flights will consist of data from the replacement, then to be operational, radiosonde as well as from the legacy radiosonde being phased out. Once dual flights begin, NCDC will expect to receive data from the dual flights in two separate data streams: data from the replacement radiosonde will arrive as part of the established operational mechanisms. NWS will place data from the legacy radiosonde into a separate FTP directory designated by NCDC for this purpose. NCDC and NWS staff will work out the necessary details and test this approach prior to the commencement of dual flights.

**Data Processing**
NCDC will place the latest raw dual flight data in a dedicated, publicly accessible FTP directory several times a day, so that NWS staff and others can access the data for real-time quality control and analysis. NCDC will process data from the replacement radiosonde in the same manner as all other operational data received from the NWS. Data from the legacy radiosonde will be processed through the same routines to the extent possible without either significantly modifying the operational system or mingling the legacy data with operational data.

**Error Reporting**
If NCDC notices transmission, formatting, or other problems during the above-mentioned processing steps, the appropriate NWS personnel will be notified. If a dual flight is culled from the results by NWS, NWS will notify NCDC. NCDC will note this information in a dedicated file and move the data from the flight into a separate directory for culled flights.

**Archiving and Access**
In addition to continuing to maintain the usual operational archive, NCDC will place both the operational and legacy data from the dual flights into a separate data set. This archive will include raw and processed data from the successful flights and raw data from failed flights. This data set, along with associated metadata and documentation, will be made available to the public through a webpage and FTP directory set up by NCDC.

**Analysis**
Once a month, NCDC will provide summaries of differences between the operational and legacy radiosondes that complement those traditionally performed by the Sterling test facility. For example, difference statistics may be computed for every location/month/time of day/variable at selected atmospheric levels. After the conclusion of all flights, the same statistics may be computed at higher vertical resolution, and the monthly comparison statistics will be aggregated into seasonal, annual, and full-study averages. Resources permitting, NCDC will also consider developing a transfer function between the legacy and replacement radiosondes, possibly using regression analysis.

**Documentation**
NCDC will prepare documentation for the archived test data set that describes the format and

origin of the data and includes relevant metadata on the test sites and instrumentation as supplied by the NWS. In collaboration with the NWS, NCDC will prepare a summary report on the study. The report will include the motivation for the study, a description of the test procedures, a summary of the analysis results, and a discussion of the implications of the results of the homogeneity of the data in the U.S. radiosonde network. The report, or a suitable version of it, will be submitted for publication in a peer-reviewed journal.

## 5.0 Test Resources

The SFSC and WSH will be responsible for procuring and shipping the majority of the test expendables. The SFSC will ensure each site has a 120 day supply of test resources at least 30-60 days in advance of the projected DCS start date. Subsequent shipments of test resources are planned to minimize site storage requirements. Items to be procured and prepared for shipping by SFSC and WSH are as follows:

- **Balloons** – The SFSC will procure 1200 gram balloons in such manner to ensure the balloon shelf life is not exceeded. Balloons will be shipped at a nominal rate of 54 balloons every 90-120 days.
- **Parachute**s – Since dual flight operations require two parachutes per balloon, shipment of extra parachutes will be coordinated by the SFSC. The SFSC will supply one parachute for each dual flight to be conducted. The other will be provided by the office using the normal NWS logistics system. The SFSC will ship approximately 48 parachutes every 90-120 days.
- **RS92 Radiosondes** – Since the RS92 radiosonde will be the operational radiosonde, they will be shipped using the normal NWS logistics system.
- **MicroART B2 Radiosonde** – Shipment of new B2 radiosondes for this test will be coordinated by OPS22. Warranty or reconditioned radiosondes will not be used in the DCS.
- **Test Sites -** Stations must have adequate staff to conduct the DCS. WSH will be responsible for funding reasonable costs incurred in the preparation of the site and during the study.
- **Spreader bars** – The SFSC will have 500 Spreader bars manufactured. The spreader bar harness assembly will be attached at the SFSC prior to shipping. Bars will be packaged in quantities of 25 and shipped two packages at a time to each site.
- **Gas** – DCS flights will require approximately 40% more gas. Stations/Region will order the additional gas and incorporate it into the stations normal delivery cycle. WSH will compensate the station/region a nominal rate of 3 tanks per month. Region should inform the WSH of the additional expense.

For non-DSC flights, the field office is required to provide all materials and resources associated with normal operations.

## 5.1 Schedule of Milestones

The test will encompass a period of approximately 60 weeks. All DCS flights will be conducted on the same day of the week at 00 UTC and 12 UTC. In order to manage cost, it is recommended the DCS flight days be Tuesday, Wednesday or Thursday. Once training is completed and SFSC personnel depart, DCS flights will be conducted on the first designated day at both synoptic times upon completion of OT&E activities. These activities will last approximately 30 days. If there are missed or unsuccessful flights the test period will be extended to make up those flights. Table 3 below is an outline of the test schedule. Once the date is set for each site to commence operational use of RRS, an actual detailed DCS schedule will be published in coordination with the site and regional personnel.

| Activity | Start | Duration |
|---|---|---|
| SFSC Pre-test activities | T – 90 Days (90 days before site starts RRS usage) | Three months |
| SFSC on site DCS training | T – 30 Days | One week |
| Site operational RRS usage | T – 30 Days | One month |
| Site DCS familiarization | T - 14 Days (Two weeks after start of RRS usage) | Two weeks |
| Test commencement | T + 0 (On selected day first week after DCS departs) | 60 weeks |
| Test debriefing | T + 60 weeks | One day |
| Test make-up flights | T + 70 First week after initial test period | 10 weeks |
| Test Wrap-up | T + 71 First non-test week after make-up flights | One day |

**Table 3. Schedule of DCS Activities**

## 5.2 Roles and Responsibilities

The following describes the roles and responsibilities during the DCS:

**Project Manager** - Jim Fitzgibbon, SFSC Site Manager
Email: james.fitzgibbon@noaa.gov Phone: 703-661-1243
Directs and manages test activities and resources. Consults with DCS Readiness Coordinator on DCS start-up activities and the Test Quality Control Manager on test progress.

**DCS Project Requirements** – Carl Bower, OPS22 Upper Air Program Manager
Email: carl.bower@noaa.gov Phone: 301-713-2093 x 115
Coordinates with National Climatic Data Center and other upper air data users on their test requirements. Reviews monthly status reports to ensure DCS data requirements are being met. Recommends changes and extends test period if minimum DCS requirements are not achieved. Coordinate compensation to regions.

**DCS Readiness Coordinator** - Ashby Hawse, SFSC Upper Air Test Program Manager
Email: ashby.hawse@noaa.gov Phone: 703-661-1222
Responsible for the certification of the RRS System and MicroART at DCS sites. Onsite team lead for all aspects of DCS operations.

**DCS Team Lead for Document Development and Review** - Ryan Brown, SFSC Research Meteorologist/Upper Air Test Team Lead
Email: ryan.brown@noaa.gov Phone: 703-661-1246
Manage development of all DCS documents. This includes test plans, user guides, training material and videos. Manages document development team.

**DCS Radiosonde Logistics Manager** – Bill Blackmore, OPS22 Operational Quality and Logistics Lead
Email: william.blackmore@noaa.gov Phone: 301-713-2093
Manages and monitors all aspects of DCS B2 radiosonde deliveries. Monitors inventory of RS92 radiosondes in Kansas City. Consultant on all aspects of DCS operations.

**DCS Helpdesk Coordinator –** Dan Brewer, SFSC on-site CyberData Team Lead/Research Meteorologist
Email: daniel.brewer@noaa.gov Phone: 703-661-1208
Manages DCS Helpdesk activities and coordinates DCS related travel.

**DCS Quality Control Meteorologist -** Katie Webster, SFSC Research Meteorologist
Email: katie.craven@noaa.gov Phone: 703-661-1234
Oversees the day-to-day DCS activities. Reviews test results on a daily basis. Generates statistics and prepares monthly progress reports. Informs appropriate personnel of test progress and problems.

**Metadata Development and Site Survey Coordinator** – Greg Kochanowicz, SFSC Research Meteorologist
Email: gregory.kochanowicz@noaa.gov Phone: 703-661-1226

Responsible for comprehensive site survey and compilation of site specific metadata.

**On Site DCS Coordinator –** Site specific, assigned locally.
Coordinates on site DCS activities, including siting of RTS and training. Informs SFSC of test related problems.

**Site Personnel -** As assigned by duty roster/shift rotation.
Evaluates current weather to determine if conditions are conducive for a successful balloon release. Informs SFSC if a flight is going to be cancelled. Performs test flights and documents all test activities on DCS web page at flight completion.

### 5.3 Expected Budget Profile

WSH will be providing funding to cover site costs for the additional support required to launch dual flights. Further guidance will be provided directly to the regions.

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